PhD research proposal

Growth of hexagonal crystal phase SiGe nanowires on m-plane substrates for integration of quantum electronics and photonics

General framework

The hexagonal crystal phase of GeSi-2H (an allotrope of the standard cubic 3C structure) has emerged as a revolutionary material which brings forward exciting photonic functionalities to the silicon technology. SiGe-2H phase exhibits a direct band gap and an excellent light emission capabilities with a tuneable emission wavelength in the mid infrared between 1.8-4.2 µm by a concentration range of 0-40% of Si.

We have pioneered the growth of Au-catalyzed Ge-2H branches on wurtzite GaAs nanowires. We have shown that the Ge branches grow in the particular <1-100> direction on the (1-100) sidewalls of the GaAs trunk. They exhibit the wanted 2H crystal structure keeping an epitaxial relationship with the GaAs trunk.

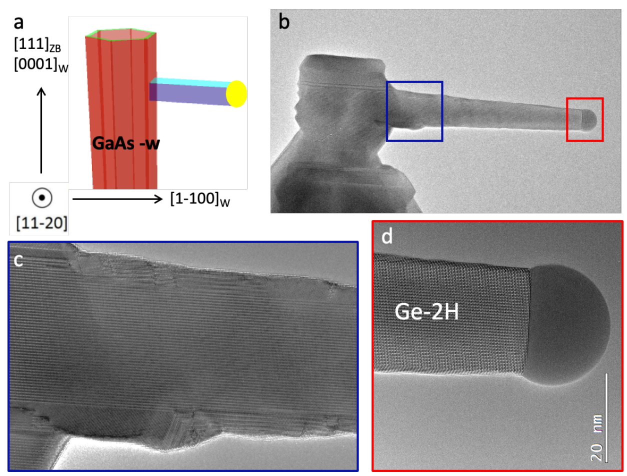

Figure: Growth of a Ge-2H branch on a wurtzite GaAs nanowire trunk. The HR-TEM images show the hexagonal crystal structure of the branch.

We aim at investigating the growth mechanisms using in-situ and real time TEM observations at the atomic scale and compare Vapor-Solid-Solid (VSS) and Vapor-Liquid-Solid (VLS) growth modes, which can be tuned by the substrate temperature. It is important to understand nucleation of this new material system with the specific <1-100> orientation and analyse the growth interface between the branch and the catalyst. We will study the crystal structure and defect formation as well as the formation of the cubic phase lateral overgrowth on the (0001) sidewalls of the branches. This fundamental study will support the fabrication of axial Si/Ge heterostructures along the unconventional <1-100> axis.

For scalable integration, nanowires must be grown on adequate hexagonal substrates with the specific m-plane {1-100} surface. In a first attempt, we will use commercially available m-plane CdS substrates. We will study the catalyst (Au and Sn) dewetting on CdS substrates and validate the possible growth of GeSi-2H nanowires on CdS or on GaAs/CdS.

This study is part of ONCHIPS project funded by the EU Horizon-CL4-2021. In the global project we aim at combining electronic and photonic qubits in the nanowires. We propose to grow enriched Ge quantum dots acting as light emitting diode (LED) in Si-rich hexagonal GeSi nanowire. To this end we will grow heterostructured GeSi-2H nanowires, control doping (p- & n-type), form junctions and embed heterostructure quantum dots in Si shell to facilitate conversion of carrier spin into photon polarization.

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Objectives and work plan

The PhD student is expected to contribute to :
- in situ TEM observations and video processing
- modelling growth mechanisms
- sample preparation and growth of nanowires on m-plane substrates
- optimisation of growth with axial abrupt heterostructures and control doping
- characterisation of structural and physical properties of the synthesized structures

Profile and skills required

We are looking for applicants with a Masters degree in Physics, Physical Chemistry, materials science or related areas with an interest in nanotechnologies. Experience with electron microscopy would be a clear advantage.

The candidate should have :
- strong knowledge in crystallography, crystal growth
- basic knowledge on python and image processing
- ability to work in cleanroom environment
- ability to work in a team and good communication skills
- upper intermediate level in English

Application

Applicants must provide by email the following documents :
- Curriculum vitae
- Details of grades obtained at university from the 1st year to present
- Motivation letter from the applicant
- Short description of the master internship
- Two recommendation letters

Deadline application 07/01/2022

Funded offer

Fully funded PhD by EU Horizon CL4
Employer : CNRS
Duration 3 years starting on 10/01/22

Contact

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